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THE PRESENT STATUS OF THE PASTEURIZATION OF MILK

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MEANING OF THE TERM PASTEURIZATION

The term "Pasteurization" originated from the experiments of Louis Pasteur, in France. From 1860 to 1864, in experiments on the "diseases" of wine, he found that heating for a few moments at temperatures of from 122° to 140° F. was sufficient to prevent abnormal fermentations and souring in wine. A little later he found that by a similar heating beer could be preserved from souring. The application of the process gave rise to the term "Pasteurization." As applied under commercial conditions, Pasteurization is the process of heating for a short or a long period, as the different processes demand, at temperatures usually between 140° and 185° F. As applied to milk for direct consumption, Pasteurization should mean a process of heating to 145° F. and holding at that temperature for 30 minutes. The process is followed by rapid cooling.

It is believed that the term "Pasteurization" should be applied only to the process of heating at 145° F. for a period of 30 minutes.

VALUE OF PASTEURIZATION

From a sanitary standpoint, the value of Pasteurization is of greatest importance when market milk is under consideration. The Pasteurization of milk, when the process is properly performed, affords protection from pathogenic organisms. Such disease-producing bacteria as *Bacillus tuberculosis*, *B. diphtheriæ*, *B. typhi*, and other organisms of the typhoid-

[1] Mr. Ayers resigned from the department in 1923. The section pertaining to extent of Pasteurization in the United States has been revised by C. S. Leete, of Market Milk Investigations.

paratyphoid group, and the dysentery bacillus, when heated at 140° F. for 20 minutes or more, are destroyed, or at least lose their ability to produce disease.

Occasionally results are reported, such as those of Twiss (30) [2] which again open the question as to the destruction of certain pathogenic organisms by Pasteurization. Using test organisms of the typhoid-paratyphoid group, she obtained results which indicated that there was not a complete destruction of these organisms when heated in milk at 140° F. and even at 149° F. for 30 minutes. Krumwiede and Noble (24), however, using some of the same test organisms of the typhoid-paratyphoid group as used by Twiss, found that they did not survive heating for 10 minutes at 140° F. They further pointed out that the apparent heat resistance of the strains used by Twiss was due to the method of determining their thermal death point.

According to Mohler (25), Pasteurization offers protection against foot-and-mouth disease. He makes the following statement:

> Milk which has been Pasteurized for the elimination of tubercle and typhoid bacilli will not prove capable of transmitting the disease (foot-and-mouth) to persons or animals fed with it.

In view of the outbreak of foot-and-mouth disease in this country a few years ago this statement is of importance.

The abortuslike bacteria in the udders of healthy cows which were demonstrated by Evans (15) may also be considered in a discussion of Pasteurization. Although their sanitary significance has not been definitely established, it is interesting to observe that it was found by Evans (16) that both the pathogenic and lipolytic varieties could be destroyed by heating to 125° F. for 30 minutes or to 145° F. for 30 seconds.

Within recent years several epidemics of septic sore throat have been traced to milk. In some of these epidemics it was found possible, by Pasteurization, to destroy streptococci which were isolated from throats of infected people and which were believed to be the infective agents. Pasteurization, properly performed, seems to protect against epidemics of this kind, but until the organism which causes the disease is definitely known it is impossible to say that it affords absolute protection.

[2] See references to literature.

Since it is quite generally believed that the streptococci are the causative agents of septic sore throat, the ability of certain of this group of organisms to stand temperatures above that of Pasteurization naturally presents a grave situation. If pathogenic streptococci are able to survive the usual process of Pasteurization, the value of the process, from a sanitary standpoint, is materially lowered.

Experience with the use of properly Pasteurized milk and the determination of the thermal death point of pathogenic streptococci by various investigators indicate very clearly, however, that the thermal death point of these organisms is relatively low and that they are readily destroyed by proper Pasteurization. Thus Hamburger (17), who studied the epidemic of septic sore throat in Baltimore in 1912, traced this epidemic to a certain milk supply. Advice was given to boil all milk, and the dairy connected with the epidemic raised the temperature of its flash Pasteurization to 160° F.; then it changed to the holder process, by which the milk was heated to 145° F. and held for a period of 30 minutes. The cases of sore throat that followed were neither so severe nor so numerous and did not follow the milk supply, but appeared to have been transmitted from individual to individual. Hamburger (18) also found that a streptococcus isolated from a patient having a case of sore throat was killed by heating in milk at 145° F. for 30 minutes.

Again, Capps and Miller (12), who studied the Chicago epidemic of septic sore throat, traced it to a dairy where the milk was Pasteurized by the flash process at 160° F. On certain dates they found that there was a pronounced failure to Pasteurize, and following these dates there were outbreaks of septic sore throat. These authors believed that the final responsibility for the epidemic rested on the inadequate and unreliable Pasteurization. They state that the absolute protection of the children of the Michael Reese Hospital from infection by efficient Pasteurization demonstrates this point. Bray (11), who studied an epidemic of tonsillitis of tuberculosis patients, traced the epidemic to a milk supply of one farm where a carrier presumably infected the milk. Forty cases of tonsillitis resulted among 400 people. As soon as the epidemic broke out the milk was Pasteurized, and from that time only one case appeared.

From the results achieved from the proper Pasteurization of milk it seems evident that the thermal death point of pathogenic streptococci, which cause septic sore throat, is relatively low. This belief is borne out by the results of the studies of Davis (13), who found that streptococci isolated from cases of sore throat were readily killed by heating at 140° F. for 30 minutes. He also found that none of 24 strains of pathogenic hemolytic streptococci of human origin resisted heating at 140° F. for 30 minutes. He makes the following statement:

> I know of no evidence that strains of streptococci pathogenic to man can resist the usual temperature of Pasteurization, 145° F., for 30 minutes.

Further evidence that pathogenic streptococci are destroyed by proper pasteurization was presented by the results obtained by Ayers, Johnson, and Davis (7), who found that 27 strains of these organisms were always destroyed by heating at 140° F. for 30 minutes.

Epidemics of scarlet fever have been traced to milk supplies, and in such cases Pasteurization has been resorted to, with apparently satisfactory results, as a means of safeguarding the public health.

Pasteurization is of value from a commercial standpoint so far as it increases the keeping quality of the milk and assists in preventing financial losses by souring. As practiced at the present time, commercial Pasteurization, with reasonable care, destroys about 99 per cent of the bacteria (this percentage varies, depending upon the proportion of heat-resistant bacteria in the milk), and while it does not prevent the ultimate souring of milk, it does delay the process. At the present time Pasteurization is the best process for the destruction of bacteria in milk on a commercial scale.

ELECTRICAL AND ULTRA-VIOLET-RAY TREATMENT OF MILK

Many attempts have been made to destroy bacteria in milk by means of electricity, but no process has been devised which has been commercially applied to any great extent.

Alternating currents have been most extensively worked with, because direct currents were found to produce undesirable chemical changes in milk. While the proper application of suitable alternating currents has resulted in bacteria reductions similar to those produced by Pasteurization, it appears to be an open question as to whether the action of the electric current is due to the heat generated or to the direct action of electricity on the bacterial cells.

Thornton (28), who studied this question in England, came to the conclusion that the destruction of bacteria must be regarded as due largely to thermal changes rather than electrical, but thought his results indicated some electrical action on the molecular structure of the bacteria. Beattie (8, 9), also working in England on the same problem, came to the conclusion that heat was not the principal factor in the destruction of bacteria by electricity, but found that to obtain satisfactory results the temperature should not be below 145° F. In the United States an electric process has been investigated by Anderson and Finkelstein (1). Their conclusion as to the cause of the destruction of the bacteria is as follows:

> The destruction of bacteria in the "———" process is apparently due to the heat produced by the electric current rather than to the electric current itself. The "———" process furnishes a method for producing a very sudden high temperature for a brief period of time.

It seems evident from a review of the literature that in the use of electricity, as it has been applied, sufficient heat is generated by electricity, or a combination of steam and electricity, to raise the milk to the Pasteurizing temperature. Since the temperatures reached are in themselves destructive to most nonspore-forming bacteria, the problem of determining whether the effect of electricity is due to heat or direct electric action is a difficult one.

The use of ultra-violet rays for the destruction of bacteria in milk has not proved to be of value as a commercial process. Experiments with these rays carried on by Ayers and Johnston (5) showed that while the rays cause great destruction of bacteria in milk, when exposed under suitable conditions, the process in its present state of development can not replace that of Pasteurization on a commercial scale. It is difficult to obtain the proper exposure of milk to the rays on a scale sufficient to permit of practical operation and impracticable to secure suitable bacteria reductions without seriously injuring the flavor of the milk.

EXTENT OF PASTEURIZATION IN THE UNITED STATES

Pasteurization when first practiced by milk dealers in this country was

carried on more or less secretly, and, except as a means of preserving the milk, was regarded by them as a process of no value. As the practice became more general the subject of Pasteurization was studied, and its value as a means of destroying disease-producing bacteria was recognized. In consequence of the recognition of the merits of the process there has been during the last 20 years a rapid increase in the quantity of milk Pasteurized. Jordan (23), in a paper published in 1913, stated that 10 years previously only about 5 per cent of the milk supply of New York City was Pasteurized; figures from other sources show that about 40 per cent in 1912, 88 per cent in 1914, and 98 per cent in 1921 was Pasteurized. In Boston very little milk was Pasteurized in 1902, but in 1915 80 per cent, and in 1924 about 97 per cent, was so treated. In many of the smaller cities there have been corresponding increases in the quantity of milk Pasteurized during the last few years.

The general tendency in this country to-day is toward the Pasteurization of all milk for direct consumption, with the exception of certified or equivalent grades of milk from tuberculin-tested herds. Some idea of the increase in the extent of Pasteurization in the United States from 1915 to 1924 may be gained by a study of Table 1. The figures were obtained from a questionnaire sent to health officers. In 1915 the figures were based on 344 replies and on 328 in 1924.

TABLE 1.—*Extent of Pasteurization of milk in cities in the United States in 1915 and 1924*

Population of cities	Number of cities		90 to 100% milk Pasteurized	50 to 90% milk Pasteurized	50 to 100% milk Pasteurized		10 to 50% milk Pasteurized		0 to 10% milk Pasteurized		None Pasteurized, per cent	
	1915	1924	1924	1924	1915	1924	1915	1924	1915	1924	1915	1924
			%	%	%	%	%	%	%	%	%	%
More than 500,000	9	9	100.0	0	77.8	100.0	22.2	0	0	0	0	0
100,001 to 500,000	40	37	56.8	35.1	30.0	91.9	50.0	8.1	15.0	0	5.0	0
75,001 to 100,000	19	19	26.3	47.3	26.3	73.6	42.1	15.8	21.0	10.6	10.6	0
50,001 to 75,000	30	25	20.0	60.0	12.3	80.0	50.0	12.0	20.0	8.0	16.7	0
25,001 to 50,000	78	60	20.0	60.0	16.7	80.0	39.7	13.3	15.4	5.0	28.2	1.7
10,001 to 25,000	168	105	12.4	33.3	6.0	45.7	23.8	31.4	10.7	2.9	59.5	20.0
10,000 and under	------	73	5.5	35.6	------	41.1	------	27.4	------	2.7	------	28.8

It will be noted that since 1915 there has been a great increase in the percentage of cities in which more than 50 per cent of the milk is Pasteurized. There has been during the same period a marked decrease in the percentage of cities having no Pasteurized milk. It seems evident that the process of Pasteurization is being used extensively in this country even in the small cities.

A study of the available figures on the extent of Pasteurization revealed a few more facts which may be of interest. In 1915 milk was Pasteurized in about 62 per cent of the cities with a population above 10,000, and in 1924 in about 89 per cent of such cities. The increase in Pasteurization in small cities with a population of 10,000 to 25,000 is shown by the fact that in 1915 about 40 per cent of these cities reported Pasteurized milk compared with 80 per cent in 1924.

Considering these figures as a whole the increasing trend of Pasteurization is plain.

A good idea of the present extent of Pasteurization may be obtained from Table 2. It will be observed that there is an increasing tendency, which follows their increasing population, for cities to have Pasteurized milk and also to Pasteurize a higher percentage of the supply.

TABLE 2.—*Proportion of cities having Pasteurized milk and average per cent of their milk supply which was Pasteurized in 1924*

Population of cities	Number of cities reporting Pasteurized milk	Number of cities with no Pasteurized milk	Per cent of cities having Pasteurized milk	Average per cent of milk Pasteurized
More than 500,000	9	0	100.00	98.1
100,001 to 500,000	37	0	100.00	81.7
75,001 to 100,000	19	0	100.00	66.6
50,001 to 75,000	25	0	100.00	66.6
25,001 to 50,000	58	2	94.4	67.0
10,001 to 25,000	84	21	80.0	42.5
Less than 10,000	53	20	72.6	33.6
Total	285	43	------	------

For those who are particularly interested in the quantity of milk pasteurized in various cities, Table 3 has been prepared. In it is a list of 315 cities that reported Pasteurized milk and the approximate quantity of milk Pasteurized. The cities are listed in order of their population given in the 1920 census and include all cities reporting Pasteurization up to the time the table was prepared. It is particularly interesting to note the extent to which milk is Pasteurized even in the small cities.

METHODS OF PASTEURIZATION

At present three processes of Pasteurization are practiced in this country. The first is known as the flash, or continuous process; the second, the holder, or holding process; and the third is known as Pasteurization in the bottle.

TABLE 3.—*Approximate quantity of milk Pasteurized in various cities as shown by returns from questionnaire sent out in 1924*

City	Population, 1920 census	Per cent of milk Pasteurized
New York City, N. Y	5, 620, 048	98. 0
Chicago, Ill	2, 701, 705	99. 0
Detroit, Mich	993, 678	98. 5
Cleveland, Ohio	796, 841	98. 0
St. Louis, Mo	772, 897	97. 6
Boston, Mass	748, 060	97. 0
Baltimore, Md	733, 826	98. 2
San Francisco, Calif	506, 676	97. 0
Washington, D. C	437, 571	95. 0
Newark, N. J	414, 524	90. 0
Cincinnati, Ohio	401, 247	98. 0
New Orleans, La	387, 219	20. 0
Minneapolis, Minn	380, 582	95. 9
Kansas City, Mo	324, 410	50. 0
Seattle, Wash	315, 312	86. 0
Rochester, N. Y	295, 750	95. 0
Portland, Oreg	258, 288	67. 0
Denver, Colo	256, 491	80. 0
Toledo, Ohio	243, 164	99. 5
Providence, R. I	237, 595	63. 3
Columbus, Ohio	237, 031	90. 0
Akron, Ohio	208, 435	99. 0
Worcester, Mass	179, 754	85. 0
Birmingham, Ala	178, 806	65. 0
Syracuse, N. Y	171, 717	92. 4
Richmond, Va	171, 667	97. 0
New Haven, Conn	162, 537	90. 0
Memphis, Tenn	162, 351	49. 7
Dayton, Ohio	152, 559	95. 0
Bridgeport, Conn	143, 555	90. 0
Houston, Tex	138, 276	66. 6
Scranton, Pa	137, 783	90. 0
Grand Rapids, Mich	137, 634	90. 0
Youngstown, Ohio	132, 358	96. 0
Springfield, Mass	129, 614	87. 7
Des Moines, Iowa	126, 468	75. 0
New Bedford, Mass	121, 217	98. 0
Fall River, Mass	120, 485	55. 0
Albany, N. Y	113, 344	75. 0
Cambridge, Mass	109, 694	95. 0
Reading, Pa	107, 784	95. 0
Spokane, Wash	104, 437	80. 0
Kansas City, Kans	101, 177	25. 0
Yonkers, N. Y	100, 176	99. 0
Duluth, Minn	98, 917	87. 0
Elizabeth, N. J	95, 283	87. 0
Lawrence, Mass	94, 270	85. 0
Utica, N. Y	94, 156	50. 0
Erie, Pa	93, 372	80. 0
Somerville, Mass	93, 091	99. 0
Waterbury, Conn	91, 715	40. 0
Flint, Mich	91, 599	85. 0
Jacksonville, Fla	91, 558	50. 0
Schenectady, N. Y	88, 723	95. 0
Canton, Ohio	87, 091	96. 0
Fort Wayne, Ind	86, 549	95. 0
Savannah, Ga	83, 252	1. 0
Manchester, N. H	78, 384	96. 0
St. Joseph, Mo	77, 939	50. 0
Knoxville, Tenn	77, 818	33. 0
El Paso, Tex	77, 560	75. 0
Harrisburg, Pa	75, 917	50. 0
Allentown, Pa	73, 502	98. 0
Wichita, Kans	72, 217	80. 0
Tulsa, Okla	72, 075	50. 0
Portland, Me	69, 272	75. 0
Terre Haute, Ind	66, 083	75. 0
Rockford, Ill	65, 651	97. 9
Saginaw, Mich	61, 903	45. 0
Springfield, Ohio	60, 840	90. 0
Mobile, Ala	60, 777	5. 0
Altoona, Pa	60, 331	97. 0
Holyoke, Mass	60, 203	82. 0
New Britain, Conn	59, 316	70. 0
Chattanooga, Tenn	57, 895	65. 0
Lansing, Mich	57, 327	85. 0
Davenport, Iowa	56, 727	55. 0
Wheeling, W. Va	56, 208	72. 0
Berkeley, Calif	56, 036	89. 0
Long Beach, Calif	55, 593	79. 5
Lincoln, Nebr	54, 948	76. 0
Portsmouth, Va	54, 387	51. 0
Haverhill, Mass	53, 884	30. 0
Lancaster, Pa	53, 150	80. 0
Macon, Ga	52, 995	25. 0
Topeka, Kans	50, 822	5. 0
Bethlehem, Pa	50, 358	90. 0
Winston-Salem, N. C	48, 395	50. 0
Quincy, Mass	47, 876	66. 6
York, Pa	47, 512	90. 0
McKeesport, Pa	46, 781	80. 0
Cedar Rapids, Iowa	45, 566	60. 0
Elmira, N. Y	45, 393	66. 6
Fresno, Calif	45, 086	95. 0
Decatur, Ill	43, 818	45. 0
Montgomery, Ala	43, 464	14. 3
Mt. Vernon, N. Y	42, 726	100. 0
Pittsfield, Mass	41, 763	33. 3
Perth Amboy, N. J	41, 707	85. 0
Lexington, Ky	41, 534	50. 0
Lima, Ohio	41, 326	100. 0
Kenosha, Wis	40, 472	95. 0
Beaumont, Tex	40, 422	2. 0
Everett, Mass	40, 120	80. 0
San Jose, Calif	39, 642	66. 7
Charlestown, W. Va	39, 608	75. 0
Dubuque, Iowa	39, 141	66. 7
Medford, Mass	39, 038	80. 0
Madison, Wis	38, 378	75. 0
Brookline, Mass	37, 748	85. 0
Taunton, Mass	37, 137	1. 0
Muskegon, Mich	36, 576	87. 5
Aurora, Ill	36, 397	98. 5
Chicopee, Mass	36, 214	70. 0
Williamsport, Pa	36, 198	60. 0
Auburn, N. Y	36, 192	90. 0
Council Bluffs, Iowa	36, 162	75. 0
Quincy, Ill	35, 978	80. 0
East Chicago, Ind	35, 967	100. 0

TABLE 3.—*Approximate quantity of milk Pasteurized in various cities as shown by returns, etc.*—Continued

City	Population, 1920 census	Per cent of milk Pasteurized
Newport News, Va	35, 596	33. 3
Stanford, Conn	35, 096	80. 0
Poughkeepsie, N. Y	35, 000	84. 8
Superior, Wis	34, 671	65. 0
Pontiac, Mich	34, 273	50. 0
Wilmington, N. C	33, 372	10. 0
Oshkosh, Wis	33, 162	10. 0
Ogden, Utah	32, 084	85. 0
Lewistown, Me	31, 794	33. 3
Newburgh, N. Y	30, 366	50. 0
Newport, R. I	30, 255	94. 3
Miami, Fla	29, 571	75. 0
Newport, Ky	29, 317	99. 0
Phoenix, Ariz	29, 053	10. 0
Fort Smith, Ark	28, 870	5. 0
Bloomington, Ill	28, 725	90. 0
Asheville, N. C	28, 504	75. 0
Nashua, N. H	28, 379	50. 0
Marion, Ohio	27, 891	75. 0
Mansfield, Ohio	27, 824	80. 0
Elgin, Ill	27, 454	66. 7
Kearny, N. J	26, 724	80. 0
Port Huron, Mich	25, 944	53. 0
Bellingham, Wash	25, 585	75. 0
Livingston, N. J	25, 480	68. 0
Sioux Falls, S. D	25, 202	98. 0
Norwood, Ohio	24, 966	97. 0
Great Falls, Mont	24, 121	33. 3
Burlington, Iowa	24, 057	40. 0
Butler, Pa	23, 778	50. 0
Marion, Ind	23, 747	20. 0
Oswego, N. Y	23, 626	50. 0
Greenville, S. C	23, 127	33. 3
Cohoes, N. Y	22, 987	50. 0
Sandusky, Ohio	22, 897	95. 0
Beverly, Mass	22, 561	60. 0
Lafayette, Ind	22, 486	33. 0
North Adams, N. Y	22, 282	00. 0
Concord, N. H	22, 167	33. 3
Gloversville, N. Y	22, 075	00. 0
Logansport, Ind	21, 626	33. 3
Boise, Idaho	21, 393	10. 0
Lockport, N. Y	21, 308	85. 0
Sharon, Pa	21, 204	40. 0
Vallejo, Calif	21, 107	90. 0
E. Liverpool, Ohio	21, 000	70. 0
Eau Claire, Wis	20, 906	50. 0
Union, N. J	20, 651	5. 0
Olean, N. Y	20, 506	33. 3
Elgin, Ohio	20, 474	75. 0
Freeport, Ill	19, 669	75. 0
Chicago Heights, Ill	19, 653	92. 0
Ann Arbor, Mich	19, 561	90. 0
Michigan City, Ind	19, 457	50. 0
Leominster, Mass	19, 445	25. 0
Santa Barbara, Calif	19, 441	40. 0
Fort Dodge, Iowa	19, 347	75. 0
Winona, Minn	19, 143	100. 0
Arlington, Mass	18, 768	80. 0
Janesville, Wis	18, 293	90. 0
Waycross, Ga	18, 068	00. 0
Alexandria, Va	18, 060	25. 0
Fairmont, W. Va	17, 851	20. 0
Hackensack, N. J	17, 667	75. 0
Alexandria, La	17, 510	00. 0
Framingham, Mass	17, 033	55. 0
Ithaca, N. Y	17, 004	33. 0
Athens, Ga	16, 748	1. 0
Berlin, N. H	16, 104	00. 0
Parsons, Kans	16, 028	00. 0
Kewanee, Ill	16, 026	95. 0
Champaign, Ill	15, 873	00. 0
St. Cloud, Minn	15, 873	75. 0
Peekskill, N. Y	15, 868	33. 3
Chillicothe, Ohio	15, 831	70. 0
Corning, N. Y	15, 820	16. 0
Ironwood, Mich	15, 739	20. 0

TABLE 3.—*Approximate quantity of milk Pasteurized in various cities as shown by returns, etc.*—Continued

City	Population, 1920 census	Per cent of milk Pasteurized
Uniontown, Pa	15, 692	33. 3
Selma, Ala	15, 589	00. 0
Walla Walla, Wash	15, 503	50. 0
Amarillo, Tex	15, 494	30. 0
Santa Ana, Calif	15, 485	75. 0
Bluefield, W. Va	15, 282	00. 0
Piqua, Ohio	15, 044	05. 0
Hornell, N. Y	15, 025	25. 0
Streaton, Ill	14, 779	80. 0
Lancaster, Ohio	14, 706	16. 0
Geneva, N. Y	14, 648	66. 0
Bridgeton, N. J	14, 323	50. 7
Huntington, Ind	14, 000	70. 0
Connellsville, Pa	13, 804	66. 0
West Allis, Wis	13, 745	00. 7
Rochester, Minn	13, 722	50. 0
Long Branch, N. J	13, 521	75. 0
Waterville, Mo	13, 351	00. 0
Saratoga Springs, N. Y	13, 181	18. 0
Chambersburg, Pa	13, 171	25. 0
Lake Charles, La	13, 088	00. 0
La Salle, Ind	13, 050	90. 0
Moberly, Mo	12, 808	66. 0
Ambridge, Pa	12, 730	50. 7
Missoula, Mont	12, 668	1. 0
Lawrence, Calif	12, 456	25. 0
Asbury Park, N. J	12, 400	97. 0
Benton Harbor, Mich	12, 233	95. 0
New Bern, N. C	12, 198	00. 0
Tuscaloosa, Ala	11, 996	40. 0
Adrian, Mich	11, 878	00. 0
Hudson, N. Y	11, 745	50. 0
Texarkana, Tex	11, 480	00. 0
Boulder, Colo	11, 006	33. 3
Biloxi, Miss	10, 937	00. 0
Johnstown, N. Y	10, 908	20. 0
Coshocton, Ohio	10, 847	15. 0
Elwood, Ind	10, 790	50. 0
Wellesley Hills, Mass	10, 749	85. 0
Charlottesville, Va	10, 688	90. 0
North Tonawanda, N. Y	10, 668	80. 0
Florence, Ala	10, 529	00. 0
Winchester, Mass	10, 485	50. 0
Provo, Utah	10, 303	75. 0
Stonington, Conn	10, 236	00. 0
Northbridge, Mass	10, 174	00. 0
Summit, N. J	10, 174	00. 0
Ilion, N. Y	10, 169	45. 0
Austin, Minn	10, 118	75. 0
Dothan, Ala	10, 034	00. 0
Dover, N. J	9, 803	00. 0
Manestie, Mich	9, 694	50. 0
Conneaut, Ohio	9, 343	25. 0
Brazil, Ind	9, 293	75. 0
Ashland, Ohio	9, 249	95. 0
Burlington, N. J	9, 049	65. 0
Chisholm, Minn	9, 039	00. 0
Wabash, Ind	9, 000	25. 0
Santa Rosa, Calif	8, 758	25. 0
Ft. Collins, Colo	8, 755	10. 0
Norfolk, Nebr	8, 634	30. 0
Grafton, W. Va	8, 517	00. 0
Mitchell, S. D	8, 478	50. 0
Wooster, Ohio	8, 204	50. 0
Mechanicville, N. Y	8, 166	10. 0
Gulfport, Miss	8, 157	7. 0
Monmouth, Ill	8, 116	10. 0
Middleborough, Ky	8, 041	20. 0
Manhattan, Kans	7, 987	10. 0
Washington Court House, Ohio	7, 962	66. 7
Winfield, Kans	7, 933	10. 0
Belvidere, Ill	7, 804	75. 0
Dublin, Ga	7, 707	75. 0
St. Albans, Vt	7, 588	00. 0
Junction City, Kans	7, 533	00. 0
Oelwein, Iowa	7, 455	33. 0

TABLE 3.—*Approximate quantity of milk Pasteurized in various cities as shown by returns, etc.*—Continued

City	Population, 1920 census	Per cent of milk Pasteurized
Galion, Ohio	7,374	20.0
Kane, Pa	7,283	70.0
Owatonna, Minn	7,252	00.0
Knoxville, Pa	7,201	00.0
Beardstown, Ill	7,111	50.0
Needham, Mass	7,012	75.0
Troy, Ohio	7,000	22.0
St. Marys, Pa	6,967	00.0
Newark, N. Y	6,964	67.0
Hillsboro, Tex	6,952	00.0
Stoughton, Mass	6,865	00.0
Elkins, W. Va	6,788	00.0
Pontiac, Ill	6,664	75.0
Rhinelander, Wis	6,654	33.0
Franklin, Mass	6,497	00.0
Rock Springs, Wyo	6,456	00.0
Lexington, Mass	6,350	80.0
Great Barrington, Mass	6,315	00.0
Wellesley, Mass	6,224	60.0
Clifton Forge, Va	6,164	00.0
Union, S. C	6,141	00.0
Pana, Ill	6,122	80.0
Maysville, Ky	6,107	25.0
Jersey Shore, Pa	6,103	33.0
Caribou, Me	6,018	00.0
Brookfield, Me	6,000	00.0
Greenwich, Conn	5,939	80.0
Palo Alto, Calif	5,900	55.0
Bowling Green, Ky	5,788	50.0
Bellevue, Ohio	5,776	100.0
Delphos, Ohio	5,745	95.0
Hillsdale, Mich	5,476	50.0
Columbus, Nebr	5,410	25.0
Danville, Ky	5,099	10.0
Canyon City, Colo	4,551	67.0
Brookings, S. Dak	3,924	100.0
Waseca, Minn	3,908	50.0
Danielson, Conn	3,130	00.0
Verona, N. J	3,039	50.0
State College, Pa	2,405	10.0
Elko, Nev	2,173	25.0
Hartsville, Ala	2,009	50.0
East Lansing, Mich	1,889	50.0

The flash process consists in heating rapidly to the Pasteurizing temperature, then cooling quickly. In this process the milk is heated from 30 seconds to 1 minute only, usually at a temperature of 160° F. or above. In view of the previously mentioned requirements for Pasteurized milk this process should not be considered suitable for proper Pasteurization. Most cities now prohibit the use of the flash process for the Pasteurization of milk.

In the holder process the milk is heated to temperatures of from 140° to 150° F. and held for approximately 30 minutes, after which it is rapidly cooled. Sometimes the milk, instead of being held at a certain temperature in one tank for 30 minutes, is merely retarded in its passage through several tanks or other retarding device so that the theoretical length of time required for the milk to pass through is about 30 minutes. In such cases, however, there is not always assurance that all the milk is held for the desired time.

Results of studies made upon continuous flow holders, both under actual commercial conditions and in the laboratory, point to the fact that careful qualitative bacteriological analysis of milk Pasteurized by this method should be made. It must be remembered that a low-count milk does not always mean a safe milk. If an apparatus is used which produces a low-count milk but which does not hold for 30 minutes, such apparatus should be viewed with distrust, for the safety factor is not assured. In many instances, the actual flow through the machine does not coincide with the theoretical flow. The holder process has almost entirely replaced the flash process, and is the one most used in this country.

The system of Pasteurization in the bottle was developed several years ago but has not come into general use. With this system the bottles of milk, usually in the cases, are placed in a compartment where the milk is heated to the desired temperature, held and cooled. With some types the bottles of milk are removed from the cases and pass slowly through the machine, being heated at the beginning and cooled at the end of the process. The heating is usually accomplished by passing sprays of hot water over the bottles. Either a special water-tight cap is used or the bottles are covered with a specially constructed pan in which there are small holes through which the hot water passes and forms a thin film around the bottles.

The advantage of this process lies in the fact that the milk after being heated is not exposed until it reaches the consumer, thereby eliminating any danger of contamination through handling.

The cost with this system is greater than with bulk Pasteurization. Extra steam and refrigeration are required, for it is necessary to heat and cool the bottles and cases in addition to the milk. Furthermore, extra space and more handling are required. This system is not in general use on a large commercial scale.

ADVANTAGES OF LOW-TEMPERATURE PASTEURIZATION

In general, the trend of Pasteurization has been toward the holder process, and with this tendency the

use of lower temperature has become more common. As a general rule, when the holder process is used milk is heated to about 145° F. for from 20 to 30 minutes and to at least 160° F. for 1 minute when the flash process is used. From bacteriological, chemical, and economical standpoints it is highly desirable that milk be Pasteurized at the lower temperature.

From a bacteriological standpoint, Pasteurization at 145° F. for 30 minutes gives assurance, so far as we know, of a complete destruction of nonspore-forming disease-producing bacteria and at the same time leaves in the Pasteurized milk the maximum percentage of the bacteria that cause milk to sour (lactic-acid bacteria) and only a small percentage of those that cause it to decompose (peptonizers). When higher temperatures are used, while the total number of all kinds of bacteria is reduced, the percentage of lactic-acid bacteria becomes less and less and the peptonizing group increases until at 180° F., or above, the lactic-acid bacteria are practically destroyed and most of the bacteria left belong to the peptonizing group. The heat-resistant lactic-acid bacteria which survive Pasteurization at 145° F. for 30 minutes play an important rôle in the souring of commercially Pasteurized milk.

From a chemical standpoint, the advantage of the lower temperature is in the fact that milk Pasteurized at 145° F. for 30 minutes does not undergo any appreciable change which should affect its nutritive value or digestibility. According to Rupp (26), the soluble phosphates of lime and magnesia do not become insoluble and the albumin does not coagulate. At 150° F. about 5 per cent of the albumin is rendered insoluble, and the amount increases with higher temperatures to 160° F., when about 30 per cent of the albumin is coagulated. The heating period in Rupp's experiments was 30 minutes.

From an economic standpoint the advantage of Pasteurization at low temperatures is in the saving in the cost of heating and cooling the milk. Bowen (10) has shown that the flash process of Pasteurization requires approximately 17 per cent more heat than the holder process. There is, of course, a correspondingly wider range through which the milk must be cooled, which also adds to the cost of Pasteurization. This is owing to the fact that in the holder process milk may be heated to 145° F. and held for 30 minutes, while to obtain the same bacteriological reduction with the flash process, with 1-minute heating, the milk would have to be heated to 165° F., and even then the complete destruction of disease-producing bacteria might be questionable.

TEMPERATURES AND METHODS MOST SUITABLE FOR PASTEURIZATION

In view of the advantages of the lower temperature for heating it is believed that the temperature of Pasteurization should be 145° F. and that the milk should be held at that temperature for 30 minutes. It has been found that heating at 140° F. for that length of time will destroy pathogenic bacteria, provided all the milk is heated to that point and held the full length of time. But it has been shown by Schorer and Rosenau (27) that it is difficult to do this under commercial conditions. These investigators tested the destruction of pathogenic organisms by inoculating milk with *B. diphtheriæ*, *B. typhi*, and *B. tuberculosis* and Pasteurizing it in 100-gallon lots under commercial conditions. They found that sometimes the organisms were not all destroyed, and in this connection state:

> Nothing in our experiment throws any doubt upon the thermal death points of the microorganisms tested. We are sure that if the milk reaches 140° F. and is held there for 20 minutes it will kill tubercle, typhoid, and diphtheria bacilli. Our experiments show that milk Pasteurized at this temperature for the specific time may not always, in practice, reach these minimum requirements. It is therefore evident that a liberal factor of safety is necessary in the operation of this type of Pasteurizer under commercial conditions.

They state further:

> Perhaps the best temperature to meet practical conditions is 145° F. and the milk should be held from 30 to 45 minutes. This should give sufficient leeway. If the Pasteurizer is set at 145° F. care will probably be taken that it does not go above 148° F. on account of destroying the cream line, and it is not likely that the mixed milk in the holding tank would drop below 140° F., which is the minimum.

Other experiments are reported by Pease and Heulings, (in the Report of the Committee on Milk Supply of American Public Health Association, 1920), in which the destruction of pathogenic organisms was tested under commercial conditions of Pasteurization. Some of the pathogenic types were found living after heating to from 140° to 141° F. and holding for 15 minutes, but none were found alive after 30 minutes' holding. Here again is evidence of the narrow margin of

safety when milk is Pasteurized at 140° F. for 30 minutes, and the committee expressed the following opinion:

> The committee feels that while enough has been done to indicate clearly that a proper application of heat to a temperature of 140° F. for a minimum period of 30 minutes will destroy substantially all the pathogenic bacteria in milk, still they believe, as already expressed, that a margin of safety for biological reasons calls for the use of higher temperatures of not lower than 145° F.

The United States Department of Agriculture, since 1910, (2) has advised the use of a temperature of 145° F. for a period of 30 minutes for the Pasteurization of milk. Besides insuring an ample margin of safety, a temperature of 145° F. causes a considerably greater destruction of bacteria in milk than 140° F. when held for the same period of 30 minutes.

Extensive experiments (3) in the research laboratories of the Bureau of Dairy Industry have shown that the thermal death point of a considerable number of bacteria lies between 140° and 145° F.; therefore an increase of 5° above 140° F. produces a great increase in the destruction of bacteria.

There is a marked tendency in commercial work to Pasteurize at or near the minimum temperature requirement necessary to destroy pathogenic organisms, namely, 140° F. Such seems to be the case because of the fear of injuring the cream line. In fact, the opinion is often expressed by milk-plant operators that a temperature of 145° F. can not be used because of the marked loss in cream line. Whittaker, Clement and others (19) have studied the effect of temperature on the cream line in a number of different plants throughout the country, and have come to the following conclusion:

Milk heated to 143° F. for 30 minutes showed practically no decrease in the cream volume, and in some cases an increase resulted.

Pasteurization at 145° to 146° F. for 30 minutes reduced the cream volume an average of approximately 8 per cent, with considerable variations above and below.

Pasteurization at approximately 148° F. for 30 minutes caused a decrease in cream volume of from 18.5 to 41.7 per cent, with an average decrease of approximately 31 per cent.

It may be said, however, that there are plants in this country, including some of the largest, in which milk is successfully Pasteurized at 145° F., and this temperature is maintained for 30 minutes. It is also interesting to note that at the 1921 meeting of the International Dairy and Milk Inspectors' Association, Pease reported experiments carried on by Heulings and him which showed that Pasteurization at 145° F. for 30 minutes did not decrease the cream line when the milk was properly heated and cooled.

The method of Pasteurization, whether it is the holder or in-the-bottle process, is not so important provided the process is such that the milk is heated to 145° F. and that all of it is held for 30 minutes. The great majority of plants Pasteurize by the holder process, and it is gratifying to observe that the flash process is but little used. Replies to a questionnaire sent to numerous cities in this country showed only 33 plants using the flash process in 18 cities out of the 266 which supplied information on this subject. Five cities reported that the flash process was not allowed, while one permitted its use but would not allow the milk to be labeled "Pasteurized." [2]

SUPERVISION OF THE PROCESS

Intelligent supervision of the Pasteurizing process is absolutely necessary and can not be provided unless there is a thorough knowledge of the primary object of Pasteurization and the bacteriological principles involved.

The primary object is the destruction of any disease-producing bacteria which may be in the milk and the handling of the Pasteurized milk in such manner that it can not be reinfected. When this object is accomplished it is found that a large percentage of the bacteria in the milk are destroyed and its keeping quality greatly improved.

The primary object can be accomplished by heating all the milk to 145° F. and holding it for a period of 30 minutes. It is then only necessary to cool the milk immediately over thoroughly cleaned and steamed coolers, to run into thoroughly cleaned and steamed, or otherwise sterilized, bottles through a thoroughly cleaned and sterilized bottle filler, then to cap the bottles with sterilized caps and place the milk in low-temperature refrigerators.

This process seems relatively simple, yet at every step problems are en-

[2] For information on Pasteurizing equipment the reader is referred to United States Department of Agriculture Bulletin No. 890, Milk-Plant Equipment.

countered which may defeat the primary object.

First of all, it must be kept in mind that bacteria are too small to be seen by the naked eye and that they are distributed in the air of the milk plant, upon the equipment with which milk comes in contact, and upon the hands of employees. Flies also carry millions of bacteria. When milk comes to the plant to be Pasteurized the logical thing to do is to see that it comes in contact only with apparatus which has been thoroughly cleaned and thoroughly steamed. Since bacteria can not be seen with the naked eye a tank or pipe apparently clean may contain many millions. Means must be taken to destroy as many of them as possible. To do this steam is usually employed, for steam at 205° F. or above for a period of 2 to 5 minutes will destroy disease-producing bacteria and all but spores of the harmless types. Equipment so treated may be called bacteriologically clean, but must be visibly clean before application of the steam if satisfactory results are to be expected.

At this point the object is to heat all the milk to 145° F. and hold it for 30 minutes. In intelligent supervision many problems are encountered at this step in the process. They are well discussed in a paper entitled "Pasteurization of Milk," which is a report of the Committee on Milk Supply of the Sanitary Engineering Section of the American Public Health Association, 1920. Briefly, the principal points are:

1. Heat all the milk to 145° F.
2. Hold all the milk for 30 minutes. (Some continuous-flow systems do not do this.)
3. Watch for leaking valves, also pipe lines which hold milk below the Pasteurizing temperature.
4. Have accurate recording thermometers so arranged as to show the total heating period. Recording thermometers should be frequently checked against a standard thermometer of unquestionable accuracy.
5. Watch for foam on the milk. This may stay in the vats for hours at a warm temperature suitable for bacterial development.

After proper heating and holding, the pathogenic organisms have been destroyed and the total number of bacteria reduced to a minimum point. The next problem is to cool and bottle the milk without reinfection, particularly with disease-producing bacteria.

To do this, bacteriologically clean coolers, bottle fillers, bottles, and sterilized caps are necessary; and what is of greatest importance is to see that the Pasteurized milk does not come in contact with human hands, or with apparatus, including bottles and caps, touched by the hands after being sterilized. The hands of milk handlers constitute perhaps the most dangerous source of reinfection in the plant, for they may convey pathogenic organisms. Through such channels milk may be contaminated by carriers of many diseases.

In order to guard against such possibilities, all employees who handle apparatus or milk in the plant or during delivery should undergo frequent medical examination, and any diseased persons or carriers should be prevented from working in positions in which they are in even indirect contact with milk, milk equipment, or delivery of the product.

It is perhaps unnecessary to say that flies are also a very serious menace to the milk supply. They must be kept out of milk plants, for it is impossible to tell when they may infect the milk. This infection can occur directly by flies getting into the milk or indirectly through contamination of equipment or containers.

At every step in the Pasteurization of milk, one is compelled to think of the process in terms of bacteria in order to supervise it intelligently.

HANDLING MILK AFTER PASTEURIZATION

Pasteurization of milk destroys about 99 per cent of the bacteria; consequently the milk is not sterile. On account of this fact, Pasteurized milk is still a perishable product, and must be handled with the same care as raw milk. This is a point for both the consumer and the milkman to remember.

Milk after Pasteurization should be cooled to about 40° F. and kept at that temperature until delivery. During warm weather it should be iced on the delivery wagons. From a sanitary standpoint all milk, whether raw or Pasteurized, should be delivered as soon as possible, in order that the consumer may get it in the best condition. In the best Pasteurized milk, when held at about 40° F., there is only a slight bacterial increase during the first 24 hours. In many cases the Pasteurization and delivery may be so arranged that the consumer gets the milk before much, if any, change has taken place in the bacterial content. For the benefit of the consumer the word "Pasteurized" should be printed on the cap, as it is only right for him to know whether he is using raw or Pasteurized milk. Some people object to Pasteurized milk, espe-

cially for infant feeding, while others desire it. It has been the experience of numerous milk dealers that the labeling of their product has greatly increased their trade.

COST OF PASTEURIZING MILK

The cost of Pasteurization in 1922 was estimated by Bowen from the cost given in his earlier paper (10) on the assumption that the average price of coal had increased 2.04 times and that milk-plant labor and equipment had increased 50 per cent over the prices of 1913, the year in which his paper was written. He obtained the information from a series of tests in five establishments which were considered to represent the average city milk plant. The Pasteurizing equipment in each consisted of a heater, a holding tank, a regenerator, and a cooler. The cost of operation was based on the Pasteurizing cycle, starting with the initial temperature of the raw milk and raising it to the Pasteurizing temperature, then cooling to the initial temperature of the raw milk. He based the costs on daily interest at 6 per cent per annum on capital invested in Pasteurizing equipment, and depreciation and repairs per day at 25 per cent per annum; interest per day at 6 per cent per annum on capital invested in mechanical equipment for Pasteurizing, such as engines, boilers, etc., and depreciation and repairs per day at 10 per cent per annum. Other costs figured were labor, coal estimated at $8.16 a ton, cooling water estimated at $0.75 per 1,000 cubic feet, and refrigeration estimated at $2 a ton. With these later estimates substituted for the old figures, Bowen calculated that the average cost of Pasteurizing 1 gallon of milk was approximately $0.0049, or a little less than one-half cent.

BACTERIA WHICH SURVIVE PASTEURIZATION

It has been stated that about 99 per cent of the bacteria in milk are destroyed by Pasteurization; consequently about 1 per cent of the bacteria remain alive, and the kinds left depend entirely on the temperature to which the milk is heated and the number of heat-resistant bacteria in the milk. From studies of the bacteria which survive Pasteurization, it is possible to show graphically the hypothetical relations of the bacterial groups in raw milk and in milk Pasteurized by the holder process at various temperatures under laboratory conditions.

The bacterial flora of the various kinds of milk is represented in Figure 1 by columns of equal length divided into sections, which, in a general way, show the relative proportion of the bacterial groups.

From the figure it may be seen that raw milk contains four principal groups of bacteria—the acid, inert, alkali, and peptonizing. The acid group is divided into two types—the acid-coagulating, which produces sufficient acid to curdle the milk within 14 days, and a type which produces acid more slowly and does not curdle the milk in 14 days. In raw milk the inert group is the largest.

In milk Pasteurized at 145° F. the great increase in the proportion of the acid-coagulating and acid groups is plainly shown. The per cent of the alkali and peptonizing groups is reduced. At 160° F. the total-acid group is still the largest, but the acid-coagulating group is made up of bacteria which coagulate very slowly. At this temperature the alkali group is greatly reduced, and the peptonizing reduced to the minimum. At 170° F. the total-acid group remains about the same, but the organisms produce acid and coagulate the milk very slowly. The alkali group is practically destroyed, although occasionally a sample may show a fairly high per cent. The most important change is in the peptonizing group. At this temperature the ratio of this group to the total number of bacteria begins to increase. The increase when milk is Pasteurized at 180° F. is even more striking. At this temperature more than 75 per cent of the bacteria which survive are peptonizers. No organisms of the acid-coagulating group are found, and only a small per cent of the acid group. Occasionally a few of the alkali group may be found. At 190° F and 200° F. the bacterial groups which survive are about the same in their relative sizes as at 180° F.

It is very evident that when the bacterial flora of Pasteurized milk is under discussion the temperature of the process is of fundamental importance. In Figure 1 the bacteria groups left in milk Pasteurized at different temperatures may be seen at a glance. It must be remembered, however, that the relations of the bacterial groups represent only average conditions and that the bacterial flora of every sample of milk must not be

expected to conform exactly to these averages. Variations in methods and conditions in the production of milk may influence considerably the bacterial group relations of an individual sample.

pose. As the milk stands, the acid formers grow and cause the milk to sour instead of decompose. When milk is Pasteurized at 180° F. for 30 minutes, however, the bacteria (lactic-acid) which cause the souring of milk are practically all destroyed, and those which are alive (peptonizing) continue to grow and cause the milk to decompose.

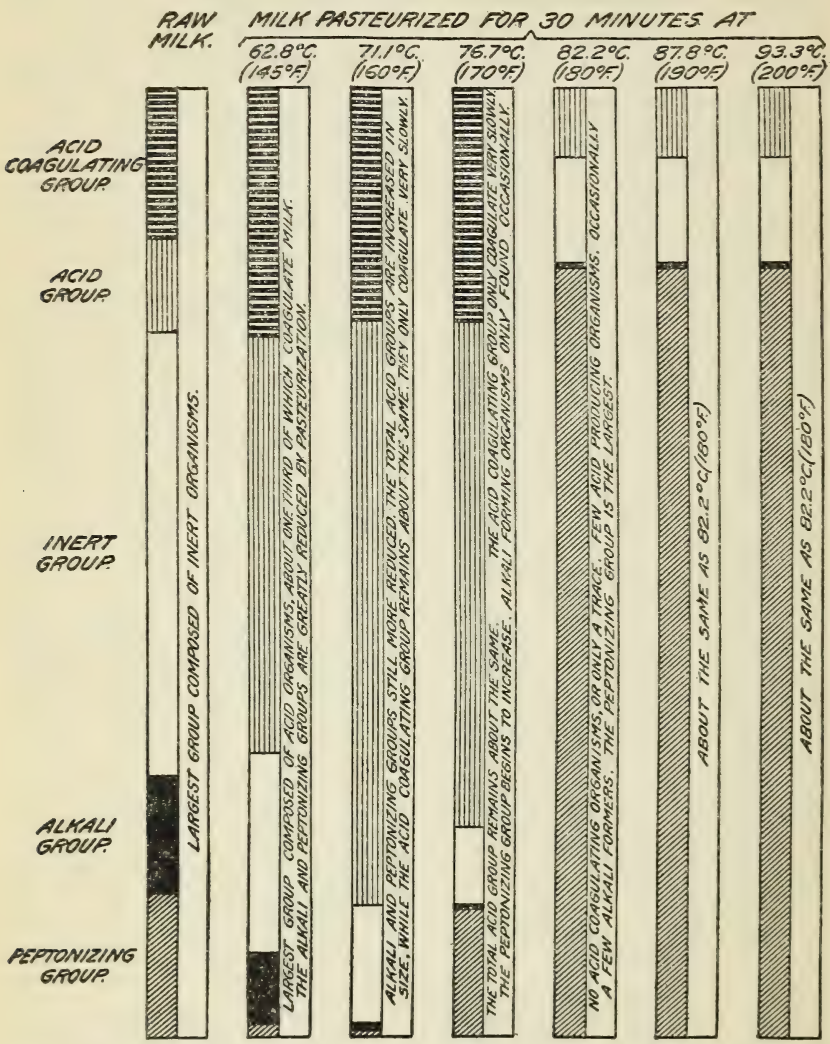

FIG. 1.—The hypothetical relation of the bacterial group to raw and Pasteurized milk

The results in Figure 1 may perhaps be better explained in popular terms. When milk is Pasteurized at 145° F. for 30 minutes, most of the bacteria (lactic-acid) left alive in it are of the kind which cause it to sour, and there are present only a few bacteria (peptonizing) which cause it to decompose. As the milk stands, the acid formers grow and cause the milk to sour instead of decompose. When milk is Pasteurized at 180° F. for 30 minutes, however, the bacteria (lactic-acid) which cause the souring of milk are practically all destroyed, and those which are alive (peptonizing) continue to grow and cause the milk to decompose.

Not only do certain types of lactic-acid bacteria survive Pasteurization but some also grow at the Pasteurizing temperature. Sometimes upon

long-continued heating at 140° to 145° F. for several hours, milk sours in the holding tanks due to the growth of these organisms. The ordinary period of holding does not provide sufficient time for their development, so this type of souring is not encountered in milk plants except when there is an interruption in the Pasteurizing process due to some abnormal condition.

SURVIVAL OF STREPTOCOCCI

Since the general groups of bacteria which survive Pasteurization have been discussed, let us now consider a more specific group. It has been the custom of some authorities to consider the presence of streptococci in Pasteurized milk an indication of an ineffective process. As already pointed out, pathogenic streptococci are readily destroyed by proper Pasteurization. In a study of the subject (4), however, it was found that certain strains of streptococci are able to survive Pasteurizing temperatures.

The thermal death points of 139 cultures of streptococci isolated from cow feces, from the udder and mouth, and from milk and cream, showed a wide variation when the milk was heated for 30 minutes under conditions similar to Pasteurization. At 140° F., the lowest Pasteurizing temperature, 89 cultures, or 64.03 per cent, survived; at 145° F., the usual temperature for Pasteurizing, 46, or 33.07 per cent, survived; and at 160° F., 3 cultures, or 2.16 per cent, survived; all these were destroyed at 165° F. The streptococci from the udder, on the whole, were less resistant and those from milk and cream more resistant to heat than those from the mouths and feces of the cows.

Two classes of streptococci seem to survive Pasteurization: (1) Streptococci which have a low majority thermal death point (the temperature at which a majority of the bacteria are killed), but among which a few cells are able to survive the Pasteurizing temperature. This ability of a few bacteria may be due to certain resistant characteristics peculiar to them or it may be caused by some protective influence in the milk. (2) Streptococci which have a high majority thermal death point, and which, when such is the case, survive because this point is above the temperature of Pasteurization. This ability to resist destruction by heating is a permanent characteristic of certain strains of streptococci.

These streptococci which have a high thermal death point above the Pasteurizing temperature undoubtedly play an important part in the occasional high counts found in Pasteurized milk. Such counts are sometimes observed when the count of the raw milk runs the same as usual. As the proportion of these heat-resistant types varies in milk their numbers may at times reach such figures that their survival of the Pasteurizing process gives an abnormally high-count product. The presence and variation of their numbers in milk, therefore, are matters which must be given consideration in connection with bacteria standards for Pasteurized milk.

It is evident that certain varieties of streptococci are able to survive Pasteurization, while others are probably always destroyed. Numerous investigators have studied the thermal death point of streptococci isolated from patients having septic sore throat and have found that the organism was destroyed by Pasteurization at 145° for 20 minutes. These results, together with the protection which proper Pasteurization seems to afford against epidemics of that disease caused by milk supplies, indicate that the varieties of streptococci associated with or responsible for the disease are among the varieties which have a low thermal death point.

THE COLON TEST FOR EFFICIENCY OF PASTEURIZATION

In a study (6) of the ability of colon bacilli to survive Pasteurization it was found that certain strains could survive Pasteurization at 145° F. for 30 minutes. On examining 174 cultures of colon bacilli it was found that at 140° F., the lowest Pasteurizing temperature, 95 cultures survived; at 145° F., the usual temperature for Pasteurization, 12 survived. In each case the heating period was 30 minutes. Considerable variation was observed in the thermal death point of the colon bacilli which survived at 145° F. When the cultures which withstood the first heating were again heated it was found that many did not survive, and in each subsequent heating different results were obtained. Colon bacilli have a low majority thermal death point but on account of the resistance of a few cells, they may survive the Pasteurizing process.

The colon test as an index of the efficiency of the process of Pasteurization is complicated by the ability of

certain strains to survive a temperature of 145° F. for 30 minutes and to develop rapidly when the Pasteurized milk is held under certain temperature conditions met during storage and delivery. Consequently the presence of a few colon bacilli in Pasteurized milk under ordinary market conditions does not necessarily indicate that the milk was not properly heated. The presence of a large number of colon bacilli immediately after the heating process indicates that the milk has not been heated to 145° F. for 30 minutes and the test properly applied should be valuable in control work. Fermentation tubes can be used for making the test, but when gas formation is noted the presence of colon bacilli should be demonstrated by further tests. Often anaerobic spore formers are encountered which survive pasteurization and give the typical fermentation tube test.

PAST AND PRESENT THEORIES OF PASTEURIZATION

Pasteurization at present is looked upon with favor by medical men, sanitarians, dairymen, and consumers, but the art has not been developed without opposition, and its value is not universally accepted. Most of the objections to Pasteurized milk have been based on theory or on experiments in which milk was Pasteurized at high temperatures. In view of our modern theories they are of no great importance.

One of the greatest objections to Pasteurized milk has been that the heating destroyed the lactic-acid bacteria and that putrefactive organisms were left, which, when relieved from the restraining action of the acid-forming bacteria, would develop, forming toxins and putrefactive products. It was believed that the milk, because it was not sour, would be consumed in that condition. This objection was based on experiments in which milk was heated to temperatures near the boiling point and can not be applied to milk Pasteurized at low temperatures. From the results of many years' work in the Bureau of Dairy Industry on commercial Pasteurized milk, it has been found that such milk sours, as raw milk does, but that the souring is delayed when compared with the souring of the same grade of raw milk. Pasteurized milk sours in a manner similar to that of a high grade of raw milk, and there is no more reason to fear the overgrowth of putrefactive organisms than there is in any high-grade milk. Pasteurization for 30 minutes at temperatures of about 145° F., as is generally practiced in this country, does not destroy all the lactic-acid organisms, and those which survive play an important rôle in the souring of commercially Pasteurized milk.

Another objection to Pasteurized milk has been that bacteria grow faster in it than in raw milk. In spite of several experiments which seem to prove this point, it has never been thoroughly established. It has been found that the rate of bacterial increase is approximately the same when the comparison is made between raw milk and Pasteurized milk having about the same bacterial content.

It is often stated that Pasteurization, even if it does destroy bacteria, does not destroy poisonous products of their growth. This can hardly be considered a real objection, for if they are present in raw milk they must be consumed with it, and if Pasteurization does not destroy them the Pasteurized milk would be no worse than raw milk.

The question as to whether Pasteurization destroys beneficial enzymes is still an open one. In the light of our present knowledge of the enzymes in milk and the part they play in the digestive process it is quite impossible to settle the question of their importance. It is evident, however, that the low temperatures now in use in Pasteurization have little effect on the commonly recognized enzymes.

The opponents of Pasteurization have raised an objection on the ground of its direct influence on the milk producer. It has been asserted that Pasteurization would cause lax methods of production on the farm, for the reason that farmers would know that the milk was to be Pasteurized and, therefore, they could be careless in its production. There seems to be some basis for this objection, but in any city where there is any inspection of the raw-milk supply the same inspection can and should be continued even though the milk is to be Pasteurized.

From a chemical standpoint serious objections have been raised against Pasteurized milk, because the heating produces changes which render the milk less digestible, particularly in the case of infants. As has already been stated, however, Rupp (26) has found that milk Pasteurized at 145° F. for 30 minutes does not undergo any appreciable chemical change. He found

that soluble phosphates do not become insoluble, that the albumin does not coagulate, and that when higher temperatures are used chemical changes do occur. He also developed the fact that 5 per cent of the albumin is rendered insoluble in milk heated for 30 minutes at 150° F., while at 160° F. 30.78 per cent of the albumin is coagulated. Further evidences that low-temperature Pasteurization does not injure the digestibility and nutritive value of milk are shown by the results of feeding experiments with babies. According to Weld (31), a number of babies that were fed raw milk and Pasteurized milk showed only a slight difference in the average net daily gain in weight during the feeding period. The slight difference was in favor of Pasteurized milk. Hess (21), however, has found that milk Pasteurized for 30 minutes at 145° F. may cause, in infants, a mild form of scurvy, which yields readily to so simple a remedy as orange juice.

High-temperature Pasteurization of earlier days must not be confused with low-temperature Pasteurization of the present day. Many of the objections which have been raised to Pasteurization have been founded on the observation of milk heated to high temperatures. The fallacy of the objections to Pasteurization have been shown, however, through scientific research in the last few years, and as a result the value of the process has been firmly established.

PASTEURIZATION AND VITAMINS

The discovery of vitamins within recent years has shown how impossible it is to estimate nutritive requirements solely in terms of digestible protein, carbohydrate, fat, and inorganic salts. Little is known of the real chemical nature of vitamins, but they are necessary for normal growth and health.

Five vitamins are now recognized—known as vitamin A (soluble in fat), vitamin B (soluble in water), the antiscorbutic vitamin C, the antirachitic vitamin D, and a vitamin concerned in reproduction originally designated X but now known as E. A and B are comparatively abundant in milk while C is present in small quantities only. D and E evidently do not occur in milk in sufficient quantities to make it an important source of these vitamins.

Because of the limited character of the infant's diet the vitamin content of its food is more important than that of the adult's, as the latter has a great variety of foods.

Fat-soluble A and water-soluble B have been found to be quite resistant to heat, and it is agreed that Pasteurization has little or no effect upon them. The antiscorbutic vitamin C, however, is quite sensitive to heat above 122° F. While the destruction of this vitamin depends upon the temperature, length, and condition of heating, as well as upon the reaction of the material in which it exists, there seems to be little doubt that Pasteurization of milk, under usual commercial conditions, at 145° F. for 30 minutes, weakens the antiscorbutic property of the milk.

Hess and Fish (20), in 1914, in studying scurvy in children found that some cases of scurvy developed when milk was used which had been pasteurized at 145° for 30 minutes.

After further studies on this subject Hess (22) made the following statement:

> Although Pasteurized milk is to be recommended on account of the security which it affords against infection, we should realize that it is an incomplete food. Unless antiscorbutics, such as orange juice, the juice of an orange peel, or potato water is added, infants will develop scurvy on this diet. This form of scurvy takes some months to develop and may be termed subacute. It must be considered not only the most common form of this disorder, but one which passes most often unrecognized. In order to guard against it, infants fed exclusively on a diet of Pasteurized milk should be given antiscorbutics far earlier than is at present the custom, even as early as the first month in life.
>
> In the course of the development of infantile scurvy, growth both in weight and in length is markedly affected. Under these conditions weight ceases to increase, and a stationary plane is maintained for weeks or for months. There is quick response, however, on the administration of orange juice or its equivalent; indeed supergrowth is thereupon frequently manifested.

PASTEURIZED MILK FOR INFANTS

A rational view must be taken of the use of Pasteurized milk. Shall the protection against infection, which is made available by the proper Pasteurization of milk, be discarded because of its deficient antiscorbutic property, or shall its protection be accepted and the deficiency in vitamin C be made up by feeding orange juice or other antiscorbutics?

Perhaps the feeding of infants calls for even further thought than is generally given. As Eddy (14) points out, there are two points to be kept in mind in infant nutrition. The first is that the vitamin content of cow's or human milk is dependent primarily on

the food eaten by the producer of the milk. In other words, milk is merely a mobilization of vitamins eaten, and if the diet is to yield a milk rich in vitamins the food eaten must also be rich. He further points out the fact that cereals are poor in vitamins and green grasses rich in them, and that this brings up the question of winter feeding if the milk supply is used for infants, and he suggests that the variability in vitamins A and B in milk may at times make it necessary to supplement the diet.

The second point brought out by Eddy expresses what appears to be the most reasonable attitude toward the use of Pasteurized milk for infant feeding according to our present knowledge of vitamins, and it is therefore quoted:

> The second point in regard to milk lies in the effect of Pasteurization. This measure is now well-nigh universal and in America at least has played a tremendous part in the reduction of infant mortality, especially in the summer months. At present, however, we know that this treatment while removing dangerous germs may also eliminate the antiscorbutic factor. The sensible attitude then is to recognize this fact and if a clean whole milk is not available retain the Pasteurization and meet the vitamin deficiency by other agents. Such agents are orange juice and tomato juice, and experience has already shown that these juices can be well tolerated by infants much earlier than used to be thought possible.

It seems, therefore, that the only serious effect of Pasteurization on the vitamins is on the antiscorbutic vitamin C, and it is evident that the feeding of orange or tomato juice, or other antiscorbutic, readily makes up for the deficiency of this vitamin in Pasteurized milk.

THE NECESSITY FOR PASTEURIZATION

The need for safeguarding the milk supply is amply proved by the numerous epidemics traced to milk. Trask (29) reported 179 epidemics of typhoid fever from 1881 to 1907, of which 107 were in the United States, 51 epidemics of scarlet fever, including 25 in this country, during the same period, and 23 epidemics of diphtheria from 1879 to 1907, including 15 in the United States. These were all traced to milk. He also listed 7 epidemics of sore throat, most of which occurred in England. Since 1907 several epidemics of septic sore throat have been traced to milk. Among these may be mentioned the epidemics at Boston, Chicago, and Baltimore, and others which have occurred in smaller cities.

The problem of Pasteurization is not based simply on the question of which is preferable, raw or Pasteurized milk, but rather upon the most economical and practical way of producing a safe milk supply.

In connection with the possibility of transmission of disease through the agency of milk, certain fundamental facts must be recognized.

1. That such possibilities exist as demonstrated by epidemics of the past.
2. That certain diseases transmitted to man, such as tuberculosis, may come from diseased animals. The danger from this source can be prevented by the elimination of tuberculous cattle from producing herds on the basis of the tuberculin test.
3. That the freeing of the herds from tuberculosis offers no protection against other diseases, as typhoid fever, diphtheria, and septic sore throat, because the pathogenic organisms causing these diseases may come from infected water supplies or probably in most cases from human carriers of disease.

The term "carriers" is used to designate persons who carry the disease-producing bacteria. In the case of diphtheria, carriers harbor the diphtheria organisms and discharge them from the nose or throat. Typhoid carriers discharge typhoid bacilli in their feces or urine. Diphtheria carriers may become so after having an acute attack of the disease or from other carriers. Typhoid carriers are particularly important, because from 2 to 4 per cent of the persons who have had typhoid fever continue, as evidence shows, to discharge the typhoid bacilli in their feces or urine or both and become chronic carriers.

Persons suffering from sore throat are a menace to the milk supply, and probably the organisms responsible for septic sore throat are sometimes carried in the throat of apparently normal individuals.

It is manifestly impossible to have a medical examination of all persons engaged in producing and handling milk. Yet such examinations at frequent intervals would be necessary, together with tuberculin testing and the assurance of unpolluted water supplies on every farm, in order to safeguard the milk supply of the Nation to the same extent that is now possible by proper Pasteurization. The appreciation of the need for Pasteurization is distinctly shown by the marked increase in Pasteurization in the United States.

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